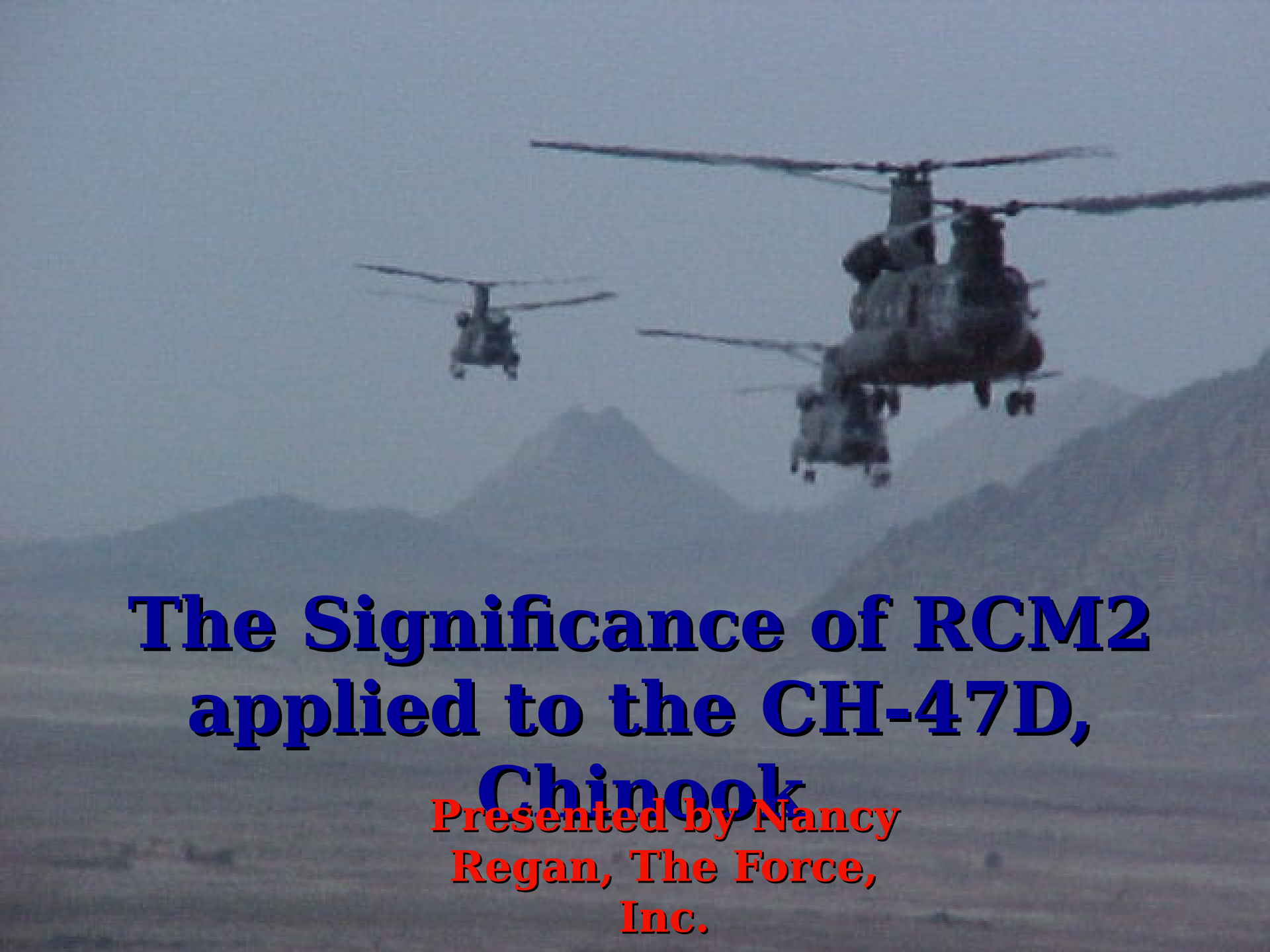


The Significance of RCM2 applied to the CH-47D, Chinook

Presented by Nancy Regan, The Force, Inc.

Agenda

- CH-47D, Chinook
- RCM Process
- Systems Analyzed
- RCM Results and Benefits
- Summary

RCM

The Traditional View of Failu

1955: Commercial Airline Industry

- Philosophy: As equipment gets older, it's more likely to fail.

85% aircraft components scheduled for overhaul or replacement

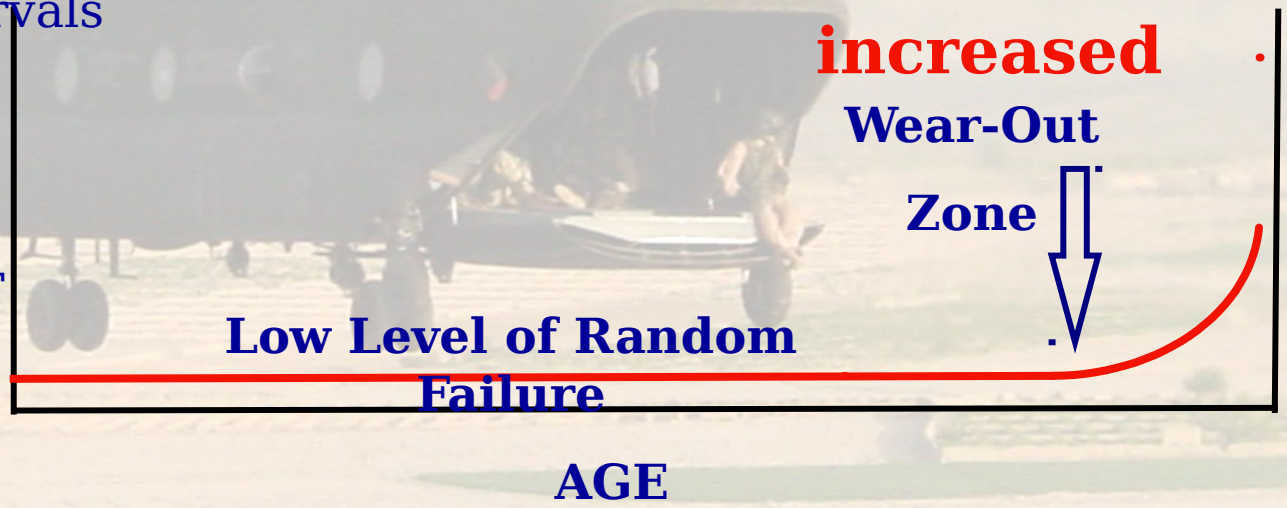
Early 1960s: Crash rate ~ 60 crashes/million takeoffs

- 67% of crashes due to component failure

Action taken to decrease crash-rate:

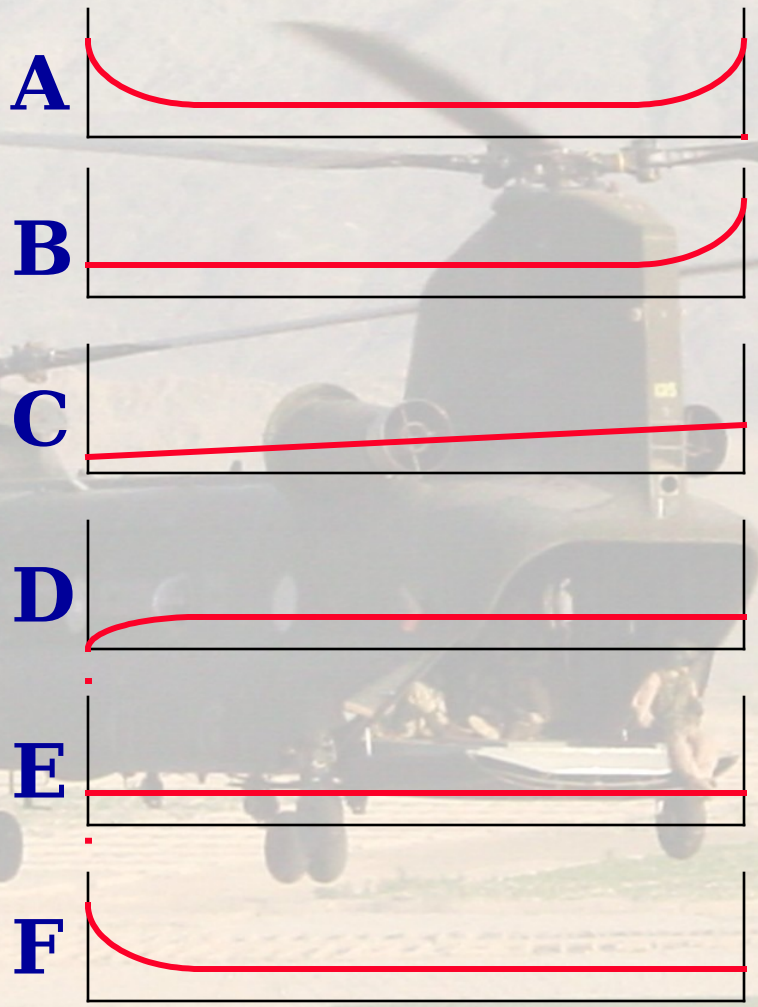
- Reduced overhaul/replacement intervals

→ Crash rate increased



Six Patterns of Failure

Stanley Nowlan and Howard Heap: Engineers, United Airlines



Bath Tub curve

4%

Slowly increasing failure rate, then wear out zone

2%

Steady increase in probability of failure

5%

Simple or complex items that have direct contact with product. Ex. Tires, Brake Pads, Pumps

Low when new, then increases to steady failure rate

7%

Random

14%

Infant mortality, then random

68%

Complex equipment. Ex. Electronics, Hydraulics, Pneumatics

Reliability Centered Maintenance 2

A process used to determine what must be done to insure that any physical asset continues to do what its users want it to do in its present operating context.

...During the return leg of a combat re-supply mission, my crew and I were in level flight (8500' PA, 32 degrees C) with an Apache (AH-64A), when we had a cockpit indication of a #2 engine chip. We executed the emergency procedure, shutdown the #2 engine, and turned for a direct route to Bagram A.B. Afghanistan. We notified the Apache of the situation and told them that we were going to start a "cruise climb" to clear the last two mountain ranges between us and the airfield. We made the decision that a precautionary landing would not be prudent due to the mine threat in the area.

Now we are single-engine, with 7 passengers, in an extreme "Hot/High" environment and still managing a 550 FPM climb well within our 30 minute temperature limits. I am guessing that it was just a couple of minutes when the Apache called and asked how high we were planning to go since they were already approaching their engine temperature limits. I said that I was at 10,300' and was planning on going to 11,000' since there were 10,500' mountains between us and the airfield. The Apache pilot asked if we had started our second engine again to climb, and I replied in the negative. The Apache pilot said that he would just "stay down here" and keep an eye on us since he was "temping out" his engines.

After leveling off at 11,000' and 105 KIAS the Apache asked if we

RCM2 Process

To Develop Justified Maintenance Requirements, the RCM Review Group Answers Seven Questions:

1. **What are its functions and associated performance standards?**
2. **In what ways can it fail?**
3. **What causes it to fail?**
4. **What happens when it fails?**
5. **Does it matter if it fails?**
6. **What can be done to predict or prevent each failure?**

RCM2 Process

1. **What are its functions and associated performance standards?**
2. **In what ways can it fai**
3. **What causes it to fail?**
4. **What happens when it fails?**

Questions 3-4: FMEA
(Failure Modes Effects Analysi

5. Does it matter if it fails?
6. What can be done to predict or prevent each failure?
7. What do we do if we cannot prevent the failure?

RCM2 Process

1. What are its functions and associated performance standards?
2. In what ways can it fail?
3. What causes it to fail?
4. What happens when it fails?
5. **Does it matter if it fails?**

Question 5: CONSEQUENCE ASSESSMENT

- Hidden
- Operational
- Safety/Environmental
- Non-Operational

6. What can be done to predict or prevent each failure?
7. What do we do if we cannot prevent the failure?

RCM2 Process

1. What are its functions and associated performance standards?
2. In what ways can it fail?
3. What causes it to fail?
4. What happens when it fails?
5. Does it matter if it fails?
6. **What can be done to predict or prevent each fa**

Question 6: **PROACTIVE TASKS**

- **On-Condition Tasks** } **Predictive Maintenance**

Application of Condition Based Maintenance (CBM)

- **TBO Items** } **Preventive Maintenance**
- **Retirement Life Items**

7. What do we do if we cannot prevent the failure?

RCM2 Process

1. What are its functions and associated performance standards?
2. In what ways can it fail?
3. What causes it to fail?
4. What happens when it fails?
5. Does it matter if it fails?
6. What can be done to predict or prevent each failure?
7. **What do we do if we cannot prevent the failure?**

Question 7: DEFAULT ACTIONS

- **Failure Finding Task**
  - Check if the item is in a failed state.
- **One-time change**
  - Physical equipment modification, change in Training, Supply, or Equipment Operating Procedure, Correction/update to Technical Publications.
- **No Scheduled Maintenance**

RCM2 Review Group

Engineer

Test Pilot

Depot Artisan

Flight Engineer

Equipment Manufacturer

Mechanic

Facilitator

Failure Data and Maintenance

- **Effective to:**
  - Determine high cost items, high maintenance man-hour consumers, etc.
  - Determine if a task is worth doing
  - Identify failure finding intervals

☜ **With respect to identifying Maintenance tasks and associated intervals, typically historical data is inadequate.**

- Reports only what failed.
- Describes what was done to repair the failure rather than what caused it.
- Doesn’t describe failures that are currently being prevented or plausible failures that haven’t occurred.
- Describes failures which may be the effect of some other failure.

RCM2 Review Group

Engineer

Test Pilot

Depot Artisan

Flight Engineer

Mechanic

Equipment Manufacturer

Facilitator

In the absence of specific data on failure rates and characteristics, intervals are largely determined based on service experience.

The Need for a Standard

- RCM2 complies fully with SAE Standard JA1011: *"Evaluation Criteria for Reliability Centered Maintenance (RCM) Processes."*

Systems Analyzed

CH-47D Systems Completed

- Flight Control System
- Advanced Flight Control System
- Flight Hydraulic System
- Power Train
- Engine Air Particle Separator
- Fuel System
- -714A Engine (including FADEC)
- -714A IETM
- 400 Flight Hour Cycle Service/Modular Daily

Results and Benefits

Power of RCM

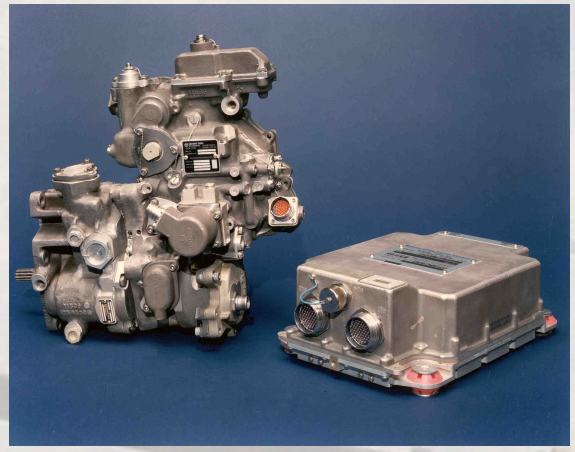
- **Reengineered Maintenance S**
  Maintenance task is generated
  an identifiable and explicit rec
- **Simulation Updates**
- **Physical Redesigns**
- **Procedural Redesigns**
- **Training Redesigns**
- **Operational Redesigns**
- **Technical Publication Redesigns**

✯ RCM applied to the Interactive Electronic Technical Manual

CH-47D RCM2 Recommendations

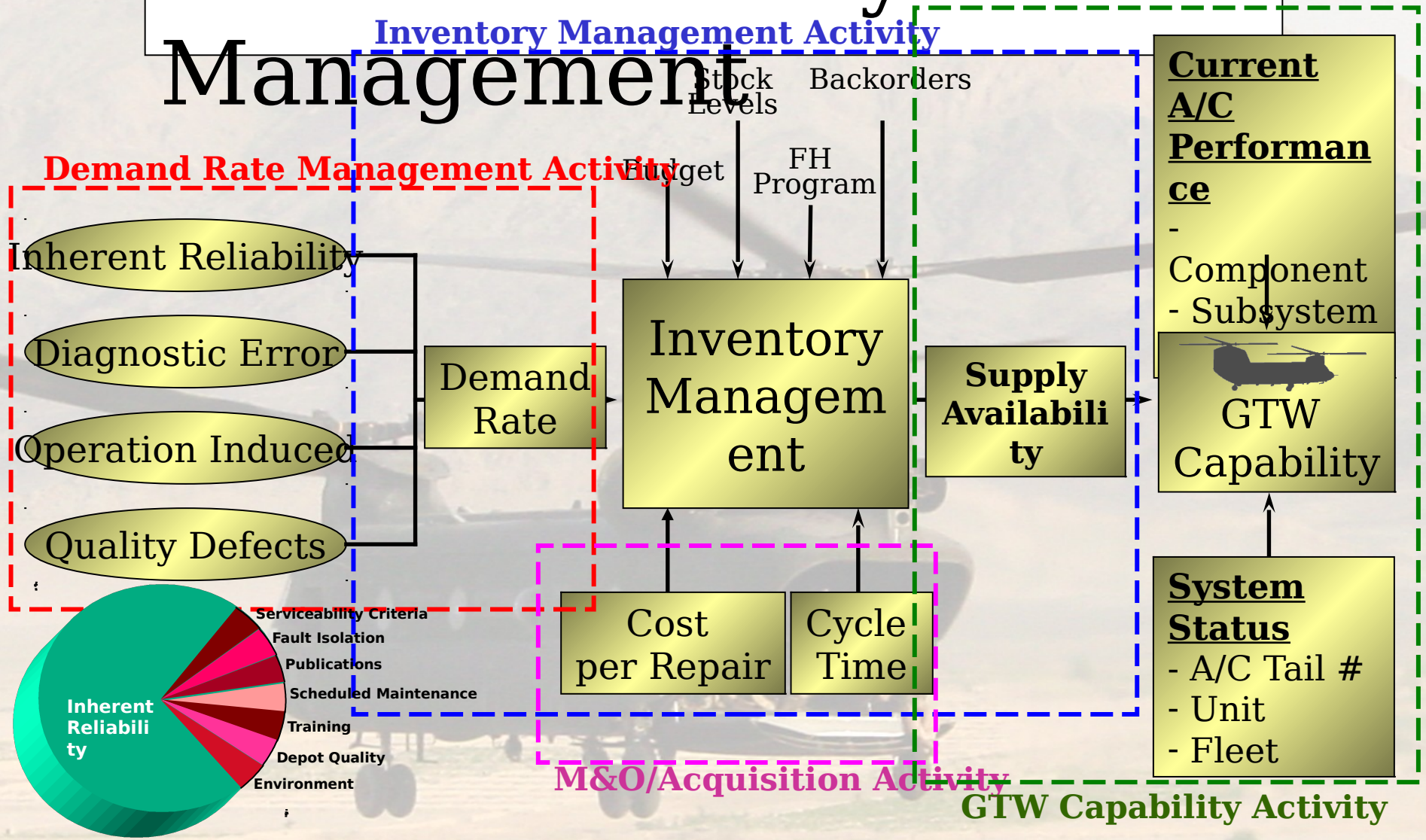
SYSTEM	RECOMMENDATIONS					
	Physical	Publications	Training	Operational	Procedural	Simulator
-714A Engine	14	16	3	1	53	0
-714A FADEC	13	18	4	8	17	2
-714A IETM	1	20	0	0	0	0
Flight Control	5	16	2	0	36	0
Flight Hydraulics	2	1	0	2	19	0
Advanced Flight Control	6	0	0	1	10	0
Power Train System	8	1	0	1	27	0
EAPS	2	5	0	0	4	0
Fuel System	1	0	0	2	0	0
Total (321)	52	77	9	15	166	2
Implemented	12	15	7	5	13	2
In-progress	37	61	2	10	152	0
Disapproved	3	1	0	0	1	0

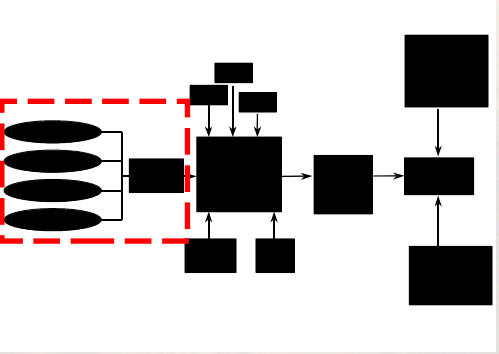
Results



- **Improved understanding of Full Authority Digital Electronic Control Unit (FADEC)**
  - ⇨ Developed an accurate and useable pilot fault code matrix
  - ⇨ Improving troubleshooting guide
- **Capitalized on -714A technology to increase readiness and reduce mission aborts**
  - ⇨ Established correct emergency and operating procedures

Focus: Inventory Management





Demand Rate Management Activity

Field Directed Insights

AMAC

2410

Cargo Baseline

LIDB

Recap Analysis

- Data Analysis
- Data Mining
- Metrics

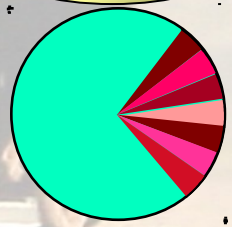
RCM2 Team Analysis

Inherent Reliability

Diagnostic Error

Operation Induced

Quality Defects



Demand Rate Reduction Opportunities

Depot Teardown Assessment

D
T
L
O
M
S

Summary

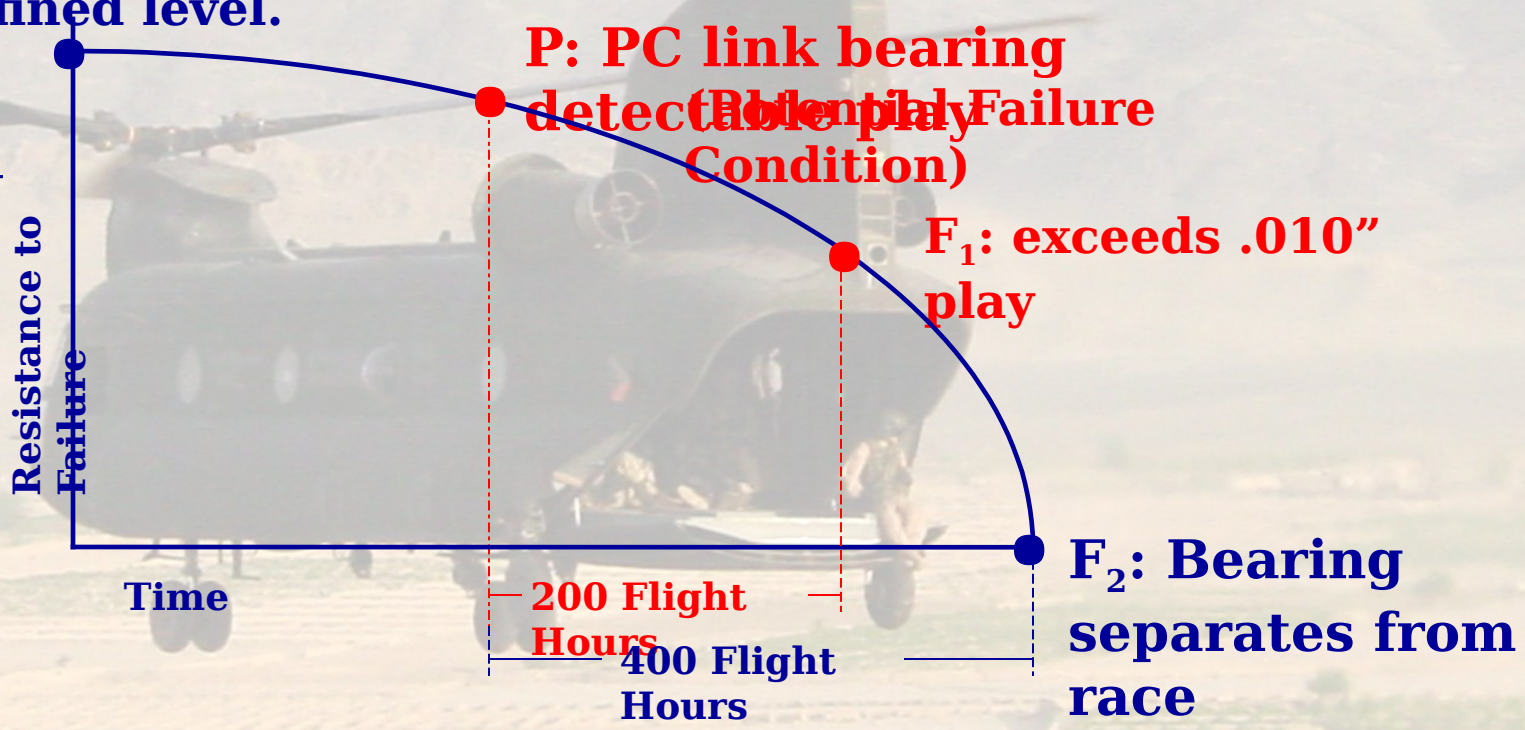
- *"We're making a big difference here."*
- *"It gives the users a voice."*

- *"This is worth a zillion dollars if we can get this information out."*
- *"It is a direct interface between us and the manufacturer."*
- *"I have never seen such enlightenments in my career."*
- *"I want to know why we aren't as good as we think we are and I want to know how we can*

Nancy Regan
ancyregan@theforceinc.com
617-921-5408

P-F Interval

- Inspection interval is governed by *how quickly* the failure occurs once it is detectable … not how often it occurs.
- The P-F interval allows inspection intervals to be sensibly assigned.
- Component remains in service until its failure resistance falls below a defined level.



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